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MARS ATMOSPHERIC ESCAPE AND ISOTOPIC FRACTIONATION: SYNTHESIS OF DATA AND MODELS. Bruce M. Jakosky (1), Janet G. Luhmann (2), and John H. Jones (3). (1) Univ. of Colorado, Boulder, CO 80309-0392; (2) IGPP/UCLA, Los Angeles, CA 90024, (3) NASA/JSC, Houston, TX 77058.

The present Mars atmosphere is relatively thin and cold. It is not at all like that which is presumed to have been responsible for the formation of valley networks and the heavy erosion of craters during the earliest epochs of martian history. An important goal of Mars exploration is to try to understand the properties of the early atmosphere, the initial inventory of volatiles at the planet's surface, the processes by which the atmosphere and climate have evolved over time, and the current location of volatiles presumed to have been in the atmosphere in the earlier times. We describe the current status of our understanding of the escape of volatiles to space over geologic time and the resulting fractionation of isotopes of stable atoms remaining in the atmosphere, and we construct a scenario for volatile abundance and evolution that is consistent with the available information on the escape and fractionation of each species. In particular, we examine the evolution of hydrogen, carbon, oxygen, and nitrogen, as contained in atmospheric (and non-atmospheric) water, carbon dioxide, and molecular nitrogen.

The following arguments and conclusions are based on the available models and measurements pertaining to the present and past atmosphere:

- (1) The enrichment of $^{15}\text{N}/^{14}\text{N}$ and $^{38}\text{Ar}/^{36}\text{Ar}$ in the present atmosphere appears to be a unique indicator of loss of volatiles to space and the resulting isotopic fractionation. The argon isotopes indicate the occurrence of sputtering loss, while the nitrogen fractionation results from both sputtering and photochemical loss.
- (2) The enrichment of D/H indicates the loss of a large fraction of the hydrogen, and hence water, in the system. Watson suggests that her recent measurements of D/H in SNC meteorites are most consistent with the observed fractionation occurring over geologic time rather than on formation of the planet.
- (3) The apparent lack of enrichment of $^{13}\text{C}/^{12}\text{C}$, despite abundant loss mechanisms, indicates the loss of less than about half of the C, derived from CO_2 , in the system.
- (4) The apparent lack of enrichment of $^{18}\text{O}/^{16}\text{O}$, also despite abundant loss mechanisms, indicates the loss of less than about half of the O in the system. Here, O is most likely derived from either CO_2 or H_2O , but may be buffered instead by interaction with silicates in hydrothermal groundwater systems.
- (5) Estimates of the total loss of C integrated over geologic time, due to both pick-up and hot-O sputtering, are equivalent to the loss of about 0.5 bars of CO_2 . This then requires the present existence of a non-atmospheric reservoir also containing at least 0.5 bars CO_2 .
- (6) Estimates of the total loss of O integrated over geologic time, due to both sputtering and photochemical loss, are equivalent to the loss of either 1.5 bars CO_2 or 30 m

water (as a global equivalent layer). Again, this then requires the present existence of a non-atmospheric reservoir of comparable or greater size.

(7) The regolith is incapable of holding enough CO₂ as adsorbed gas to account for the non-atmospheric reservoir of C. However, CO₂ is stable at the poles as long as it is confined beneath an overlying layer of water ice only a few tens of centimeters to meters thick; this is the case even at the north, where CO₂ is not stable at the surface. Thus, the polar ice deposits may contain sufficient CO₂ to account for this reservoir. This CO₂ could be released at the highest obliquities.

(8) The size of the required oxygen buffer could be accommodated by polar water ice, polar CO₂ ice, or some combination of the two. Non-polar H₂O or CO₂ is probably not as likely to be exchangeable in the required abundances.

If this scenario is correct, then the polar deposits are primarily CO₂ ice, and there is relatively little exchangeable water in the system (perhaps only a layer of water ice 100 m thick at the north pole). Clearly, there is much more water than this in the martian environment. The C and O isotopic evidence suggests that any excess water is rapidly removed from the exchangeable system; for instance, much of the water from the outflow channels would have to have been frozen out and trapped in the northern lowlands without becoming a part of the atmosphere-polar cap-regolith system.

Unlike previous descriptions of the evolution of martian volatiles from a geochemical perspective, the scenario we present appears to be consistent with the geomorphological evidence for climate change. That is, our model is consistent with the existence of about a bar of CO₂ in the martian environment during the earliest epochs, with half of that being lost to space and half being sequestered into a polar reservoir; the timescales for the occurrence of these events are consistent with the requirement for a thicker early atmosphere to allow formation of valley networks and degradation of craters.